

Unparticle Effects on Top Quark Pair Production at Photon Collider

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Abstract

The unparticle effects on $t\bar{t}$ production at the future photon collider are investigated. Distributions of $t\bar{t}$ invariant mass and that for transverse momentum of top quark with respect to Standard Model and unparticle production are predicted. An odd valley with scalar unparticle contribution appears for some values of d_u , which is due to the big cancellation between the contribution from SM and that from unparticle. This character may be used to study the properties of scalar unparticle. Our investigations also show that scalar unparticle may play a significant role in $t\bar{t}$ production at photon collider if it exists.

Key Words: unparticle, top quark, linear collider

PACS: 14.80.-j, 14.65.Ha, 12.90.+b, 12.38.Qk

1 Introduction

It is believed that new physics beyond Standard Model (SM) must exist due to the neutrino oscillation. But up to now, nobody knows exactly what the origin of new physics is. Though many investigations within the frame work of, for example, various extensions of SM Higgs doublet model, minimal supersymmetric extension of SM, technicolor, extra dimension, etc, have already been finished, more ideas on new physics are still necessary. Recently, Motivated by Banks-Zaks theory [1], Georgi proposes a fantastic idea, called unparticle physics [2]. It is a low energy effective description of a scale invariant sector with a continuous mass distribution. In Georgi's scheme, the scale invariant sector ($\mathcal{B}\mathcal{Z}$ sector) [1] interacts with the SM by exchanging particles with a very high mass scale $M_{\mathcal{U}}^k$

$$\frac{1}{M_{\mathcal{U}}^k} O_{SM} O_{\mathcal{B}\mathcal{Z}} , \quad (1)$$

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where O_{SM} ($O_{\mathcal{B}Z}$) represents local operator constructed out of standard model ($\mathcal{B}Z$ fields) with scale dimension d_{SM} ($d_{\mathcal{B}Z}$). Renormalization effects of the $\mathcal{B}Z$ sector induce dimensional transmutation at an energy scale $\Lambda_{\mathcal{U}}$. Below the scale $\Lambda_{\mathcal{U}}$, $O_{\mathcal{B}Z}$ matches onto unparticle operator $O_{\mathcal{U}}$ and Eq.(1) becomes

$$C_{O_{\mathcal{U}}} \frac{\Lambda_{\mathcal{U}}^{d_{\mathcal{B}Z}-d_{\mathcal{U}}}}{M_{\mathcal{U}}^k} O_{SM} O_{\mathcal{U}}, \quad (2)$$

where $C_{O_{\mathcal{U}}}$ is a coefficient function and $d_{\mathcal{U}}$ the scale dimension of the unparticle operator. Recently, many phenomenology studies on unparticle have been finished [3].

On the other hand, top quark physics will play an important role in testing the SM and finding new physics near TeV scale. This kind of topic is widely investigated at Tevatron, LHC and the future linear collider (LC) [4]. The effects of unparticle-couplings of the SM fields (matter and gauge) in top quark pair production at the Tevatron and LHC are studied in ref. [5]. It is found in ref. [6] that the existence of unparticle may lead to measurable enhancements on the SM predictions. Comparing with $e^+e^- \rightarrow t\bar{t}$ process, $\gamma\gamma \rightarrow t\bar{t}$ process will provide information on possible anomalous $\gamma t\bar{t}$ couplings without contributions from $Zt\bar{t}$ couplings [7] and some useful clues on photon photon interactions. Heavy quark production in polarized $\gamma\gamma$ collisions will also help to determine the parity of the intermediate state, e.g. Higgs boson produced as a resonance or unparticle, etc. In this paper, we study the unparticle effects on $t\bar{t}$ production at the future photon collider.

The effective interaction between unparticle operators and SM field should satisfy the SM gauge symmetry and be Lorentz invariant. The economical forms of interaction between gauge bosons and unparticle are [8]

$$\frac{C_K}{\Lambda_{\mathcal{U}}^{d_{\mathcal{U}}}} G_{\alpha\beta} G^{\alpha\beta} O_{\mathcal{U}}, \quad \frac{C_K}{\Lambda_{\mathcal{U}}^{d_{\mathcal{U}}}} G_{\alpha\mu} G_{\nu}^{\alpha} O_{\mathcal{U}}^{\mu\nu} \quad (3)$$

where $G_{\alpha\beta}$ denotes the gauge boson field, C_K the gauge boson coupling of scalar unparticle. The vector and tensor unparticle operators are Hermitian and transverse [8],

$$\partial_{\mu} O_{\mathcal{U}}^{\mu} = 0, \quad \partial_{\mu} O_{\mathcal{U}}^{\mu\nu} = 0 \quad (4)$$

Additionally, the tensor unparticle operator is assumed to be traceless $O_{\mathcal{U}\mu}^{\mu} = 0$. Using these interaction Hamiltonians, we can obtain Feynman rules for the unparticle and gauge boson interaction. There is no vector unparticle interacting with gauge boson due to the Lorentz invariant and transverse condition of unparticle. The corresponding Feynman rules used in this paper are listed as follows [8]:

Unparticle propagators:

$$\begin{aligned}\Delta_F(P^2) &= \frac{i A_{d_u}}{2 \sin(d_u \pi)} (-P^2)^{d_u-2}, & \text{for Scalar unparticle,} \\ [\Delta_F(P^2)]_{\mu\nu, \rho\sigma} &= \frac{i A_{d_u}}{2 \sin(d_u \pi)} (-P^2)^{d_u-2} T_{\mu\nu, \rho\sigma}(P), & \text{for Tensor unparticle,}\end{aligned}$$

with P the four momentum of the unparticle, and

$$\begin{aligned}(-P^2)^{d_u-2} &= \begin{cases} |P^2|^{d_u-2} & \text{for } P^2 \text{ is negative and real,} \\ |P^2|^{d_u-2} e^{-id_u \pi} & \text{for } P^2 \text{ is positive.} \end{cases} \\ A_{d_u} &= \frac{16\pi^2 \sqrt{\pi}}{(2\pi)^{2d_u}} \frac{\Gamma(d_u + \frac{1}{2})}{\Gamma(d_u - 1)\Gamma(2d_u)}, \\ T^{\mu\nu, \rho\sigma}(P) &= \frac{1}{2} \left\{ \pi^{\mu\rho}(P) \pi^{\nu\sigma}(P) + \pi^{\mu\sigma}(P) \pi^{\nu\rho}(P) - \frac{2}{3} \pi^{\mu\nu}(P) \pi^{\rho\sigma}(P) \right\}, \\ \pi^{\mu\nu}(P) &= -g^{\mu\nu} + \frac{P^\mu P^\nu}{P^2}.\end{aligned}$$

Vertices w.r.t. scalar unparticle

- $i \frac{C_S}{\Lambda_u^{d_u-1}} - \frac{C_P}{\Lambda_u^{d_u-1}} \gamma^5 + \frac{C_V}{\Lambda_u^{d_u}} \not{P}$ for $t\bar{t}u$
- $4i \frac{C_K}{\Lambda_u^{d_u}} (-p_1 \cdot p_2 g^{\mu\nu} + p_1^\nu p_2^\mu)$ for $\gamma\gamma u$

where C_S , C_P and C_V respectively denote scalar, pseudoscalar and vector couplings of scalar unparticle, p_1 (p_2) the momentum of the corresponding photon, and u the unparticle. The vertex $\frac{C_V}{\Lambda_u^{d_u}} \not{P}$ does not contribute to the process because the final state fermion current is on-shell.

Vertices w.r.t. tensor unparticle

- $-\frac{i\lambda_T}{4\Lambda_u^{d_u}} [\gamma^\mu (p_1^\nu - p_2^\nu) + \gamma^\nu (p_1^\mu - p_2^\mu)]$ for $t\bar{t}u$
- $i \frac{\lambda_T}{\Lambda_u^{d_u}} [K^{\mu\nu\rho\sigma} + K^{\mu\nu\sigma\rho}]$ for $\gamma\gamma u$

with $K^{\mu\nu\rho\sigma} = -g^{\mu\nu} p_1^\rho p_2^\sigma - p_1 \cdot p_2 g^{\rho\mu} g^{\sigma\nu} + p_1^\nu p_2^\rho g^{\sigma\mu} + p_2^\mu p_1^\rho g^{\sigma\nu}$. λ_T is the dimensionless effective coupling constant.

This paper is organized as follows: the analytical results for $t\bar{t}$ production in $\gamma\gamma$ collisions related to SM and unparticle process are listed in Sec.2, and the numerical results are shown in Sec.3. Finally we give a brief summary.

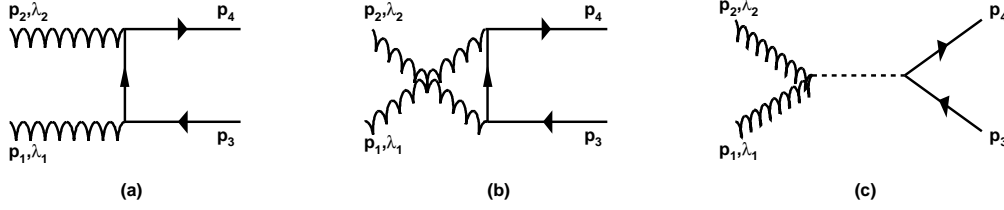


Figure 1: Feynman diagrams for $t\bar{t}$ production. (a) and (b): SM contribution. (c): via virtual unparticle propagator.

2 $t\bar{t}$ Production in $\gamma\gamma$ Collisions

At a photon collider, top quark pair can be produced within SM (Fig.1(a), (b))

$$\gamma(p_1, \lambda_1) + \gamma(p_2, \lambda_2) \xrightarrow{SM} \bar{t}(p_3) + t(p_4), \quad (5)$$

or via Non-SM particle, e.g. unparticle (Fig.1(c))

$$\gamma(p_1, \lambda_1) + \gamma(p_2, \lambda_2) \xrightarrow{u} \bar{t}(p_3) + t(p_4), \quad (6)$$

where p_i ($i = 1, 2, 3, 4$) respectively denote the momenta of the corresponding particles, λ_1 (λ_2) the initial photon helicity. The differential cross section for $t\bar{t}$ pair production can be written as:

$$d\hat{\sigma}(\lambda_1, \lambda_2) = \frac{1}{2\hat{s}} |\mathcal{M}|^2 d\Gamma_2, \quad (7)$$

where $\hat{s} = (p_1 + p_2)^2$ and $d\Gamma_2$ the two-particle phase space. The invariant amplitude for $t\bar{t}$ production at photon collider $\mathcal{M} = \mathcal{M}_{SM} + \mathcal{M}_u$ with \mathcal{M}_{SM} for process (5) and \mathcal{M}_u for process (6). Then we can obtain the matrix element square as follows:

Scalar unparticle

$$\begin{aligned}
|\mathcal{M}|^2 &= N_c \left[\frac{C_K}{\Lambda_u^{2d_u-1}} \frac{A_{d_u}}{\sin(d_u \pi)} \right]^2 \hat{s}^{2d_u-1} (1 + \lambda_1 \lambda_2) (C_P^2 + \beta^2 C_S^2) \\
&+ \frac{32 N_c \pi \alpha A_{d_u} Q_t^2 C_K}{\Lambda_u^{2d_u-1}} \frac{\hat{s}^{d_u-1} m}{(\beta^2 z^2 - 1)} \left[C_P (\lambda_1 + \lambda_2) - \beta^2 C_S (1 + \lambda_1 \lambda_2) \cot(d_u \pi) \right] \\
&+ |\mathcal{M}_{SM}|^2,
\end{aligned} \tag{8}$$

with $N_c = 3$, the number of colors, and

$$\begin{aligned}
|\mathcal{M}_{SM}|^2 &= \frac{64 N_c \alpha^2 Q_t^4 \pi^2}{(1 - \beta^2 z^2)^2} \left\{ 1 + 2\beta^2 (1 - z^2) - \beta^4 [1 + (1 - z^2)^2] \right. \\
&\quad \left. + \lambda_1 \lambda_2 [1 - 2\beta^2 (1 - z^2) - \beta^4 z^2 (2 - z^2)] \right\},
\end{aligned} \tag{9}$$

where α is the fine structure constant, $Q_t = 2/3$, m the top quark mass, $\beta = \sqrt{1 - 4m^2/\hat{s}}$, and $z = \hat{\mathbf{p}}_1 \cdot \hat{\mathbf{p}}_4$, with $\hat{\mathbf{p}}_1$ ($\hat{\mathbf{p}}_4$) the direction of the initial photon (top quark) in the $\gamma\gamma$ Center of Mass System (CMS). $|\mathcal{M}_{SM}|^2$ agrees with that in ref. [9].

Tensor unparticle

$$\begin{aligned}
|\mathcal{M}|^2 &= N_c \left[\frac{\lambda_T^2}{8\Lambda_u^{2d_u}} \frac{A_{d_u}}{\sin(d_u \pi)} \right]^2 \hat{s}^{2d_u} \left\{ \beta^2 (\lambda_1 \lambda_2 - 1) (z^2 - 1) [2 + \beta^2 (z^2 - 1)] \right\} \\
&+ \frac{2\pi N_c \alpha A_{d_u} Q_t^2 \lambda_T^2}{\Lambda_u^{2d_u}} \frac{\hat{s}^{d_u}}{(\beta^2 z^2 - 1)} \left\{ \beta^2 (\lambda_1 \lambda_2 - 1) (z^2 - 1) [2 + \beta^2 (z^2 - 1)] \cot(d_u \pi) \right\} \\
&+ |\mathcal{M}_{SM}|^2
\end{aligned} \tag{10}$$

The terms in the second line of Eq.(8) and (10) are the interference terms between SM and unparticle process.

3 Numerical results for $\gamma\gamma \rightarrow t\bar{t}$

The future linear collider is a large scale project in accelerator particle physics with electron-positron colliding at energies from 0.5 TeV up to about 1 TeV [10]. LC can be operated in photon photon mode, where high energy photons can be obtained by Compton backscattering of laser light off the high energy

electron beam [11]. Combining the results in Sec.2, we obtain the effective cross section for top quark pair production at the LC

$$\sigma(S, P_{e1}, P_{e2}, P_{L1}, P_{L2}) = \int_0^{y_{max}} dy_1 \int_0^{y_{max}} dy_2 f_\gamma^e(y_1, P_{e1}, P_{L1}) f_\gamma^e(y_2, P_{e2}, P_{L2}) \hat{\sigma}(\hat{s}, \lambda_1, \lambda_2) \quad (11)$$

The function $f_\gamma^e(y, P_e, P_L)$ is the normalized energy spectrum of the photons

$$f_\gamma^e(y, P_e, P_L) = \mathcal{N}^{-1} \left[\frac{1}{1-y} - y + (2r-1)^2 - P_e P_L x r (2r-1)(2-y) \right], \quad (12)$$

where \sqrt{S} is the e^+e^- CMS energy, \mathcal{N} the normalization factor, P_e (P_L) the polarization of the initial electron (laser) beam, $r = y/(x-xy)$, and y is the fraction of the electron energy transferred to the photon in the center of mass frame. It has the following range

$$0 \leq y \leq y_{max} \equiv \frac{x}{x+1}, \quad x = \frac{4E_L E_e}{m_e^2}, \quad (13)$$

with m_e is the electron mass and E_e (E_L) the energy of the electron (laser) beam. In order to avoid the creation of an e^+e^- pair from the backscattered photon and the initial photon, one has to set $x \leq 2(1+\sqrt{2})$. $\lambda_i (i=1,2)$ presented in the cross section $\hat{\sigma}(\hat{s}, \lambda_1, \lambda_2)$ is now given by

$$\lambda_i = P_\gamma(y_i, P_{e(i)}, P_{L(i)}), i=1,2, \quad (14)$$

where the function $P_\gamma(y, P_e, P_L)$ is the polarization of photons scattered with energy fraction y ,

$$P_\gamma(y, P_e, P_L) = \frac{1}{f_\gamma^e(y, P_e, P_L) \mathcal{N}} \{ x r P_e [1 + (1-y)(2r-1)^2] - (2r-1) P_L [\frac{1}{1-y} + 1-y] \}. \quad (15)$$

In our numerical calculation, we adopt the inputs $E_e = 250 \text{ GeV}$, $E_L = 1.26 \text{ eV}$, $m_e = 5.11 \times 10^{-4} \text{ GeV}$, $m_t = 172.5 \text{ GeV}$ and $\alpha = 1/128$. In order to give a naive estimation at LC, we set

$$C_K = C_P = C_S \equiv \lambda_S, \quad (16)$$

where λ_S denotes the dimensionless effective coupling constant. Top quark pair production with unparticle effects at Tevatron is first calculated in [5], where the constraints on the unparticle energy scale $\Lambda_{\mathcal{U}}$ are obtained. When $d_{\mathcal{U}} = 1.1(2.01)$ and $\Lambda_{\mathcal{U}} > 600(1200) \text{ GeV}$, the total cross section for $t\bar{t}$ production at Tevatron given in [5] is within the 95% C.L. upper limit of CDF experiment data. Using the same parameters as [5], we give the total cross section for $t\bar{t}$ production at photon collider in fig.2. The leading order (LO) and next-to-leading order (NLO) SM predictions are also shown in the same figure.

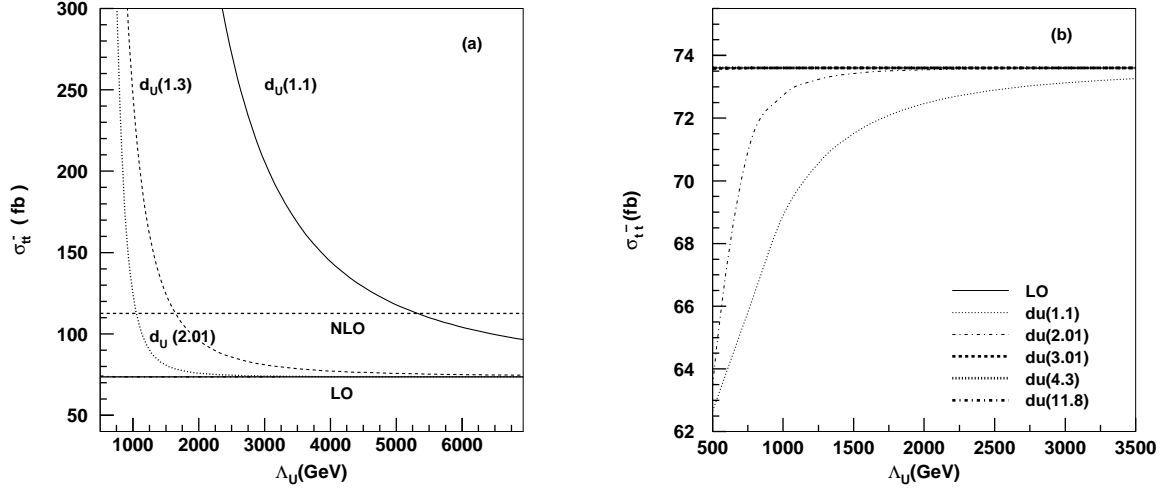


Figure 2: The total cross section for $t\bar{t}$ production at photon collider (a) unpolarized beams with scalar unparticle. (b) unpolarized beams with tensor unparticle.

Assuming the new physics effects are not far away from SM predictions and demanding the total cross section for $t\bar{t}$ production is between LO and NLO QCD prediction, we can obtain some constraints on $\Lambda_{\mathcal{U}}$ with scalar unparticle in fig.2(a). Our results indicate that $\Lambda_{\mathcal{U}}$ should be larger than 5500 (1000) GeV when $d_{\mathcal{U}} = 1.1$ (2.01). This is consistent with the results in ref. [5]. The total cross section with tensor unparticle in fig.2(b) is small for $\Lambda_{\mathcal{U}} > 1.5$ TeV. We also investigate the cross section w.r.t. tensor unparticle for different $d_{\mathcal{U}}$. Obviously, for $d_{\mathcal{U}} > 3$, the tensor unparticle effects can almost be neglected. To illustrate the unparticle effects on $t\bar{t}$ production, we define the following dimensionless variables

$$R_{\mathcal{U}}^{S(T)} = \frac{\sigma_{SM+\mathcal{U}}^{S(T)} - \sigma_{SM}}{\sigma_{SM}}, \quad R^{S(T)} = \left| \frac{\frac{d\sigma_{SM+\mathcal{U}}^{S(T)}}{dM_{t\bar{t}}} - \frac{d\sigma_{SM}}{dM_{t\bar{t}}}}{\frac{d\sigma_{SM}}{dM_{t\bar{t}}}} \right|, \quad r^{S(T)} = \left| \frac{\frac{d\sigma_{SM+\mathcal{U}}^{S(T)}}{dP_t} - \frac{d\sigma_{SM}}{dP_t}}{\frac{d\sigma_{SM}}{dP_t}} \right|, \quad (17)$$

where σ_{SM} denotes the effective cross section within SM, $\sigma_{SM+\mathcal{U}}^{S(T)}$ the cross section of SM plus scalar (tensor) unparticle contribution, $M_{t\bar{t}}$ the $t\bar{t}$ invariant mass, and P_t the transverse momentum of top quark. In Table 1, we provide our numerical results for the effective cross section within SM⁵ and $R_{\mathcal{U}}^{S(T)}$ with $\lambda_S = \lambda_T = 1$, and $\Lambda_{\mathcal{U}} = 1 \text{ TeV}$. When $d_{\mathcal{U}}$ is close to 2, $R_{\mathcal{U}}^{S(T)}$ becomes slightly large due to the singularities of the propagator⁶. The unparticle effects induced by individual scalar operator are given in Table 2. It

⁵Our results agree to those obtained in ref. [9].

⁶we use the propagators for a scale invariant sector which differs from a conformal invariant hidden ones in ref. [12].

$(P_{e1}, P_{e2}; P_{L1}, P_{L2})$	$\sigma_{SM}(fb)$	$d_{\mathcal{U}} = 1.3$		$d_{\mathcal{U}} = 1.5$		$d_{\mathcal{U}} = 1.95$		$d_{\mathcal{U}} = 2.01$	
		$R_{\mathcal{U}}^S$	$R_{\mathcal{U}}^T$	$R_{\mathcal{U}}^S$	$R_{\mathcal{U}}^T$	$R_{\mathcal{U}}^S$	$R_{\mathcal{U}}^T$	$R_{\mathcal{U}}^S$	$R_{\mathcal{U}}^T$
(0,0;0,0)	73.6	2.3	-0.01	0.2	0.0001	-0.01	0.004	0.7	-0.01
(0.85,0.85;-1,-1)	228.6	0.8	-0.001	-0.6	0.00001	-0.08	0.0004	0.9	-0.001
(0.85,0.85;+1,+1)	29.0	0.7	-0.008	-0.4	0.00006	-0.04	0.002	0.6	-0.007
(0.85,-0.85;-1,+1)	78.6	0.8	-0.06	0.09	0.0005	-0.001	0.02	0.2	-0.05

Table 1: Results for the effective cross section within SM and $R_{\mathcal{U}}^{S(T)}$ ($\lambda_S = \lambda_T = 1$) at $\sqrt{S} = 500GeV$.

$(P_{e1}, P_{e2}; P_{L1}, P_{L2})$	$R_{\mathcal{U}}^S$							
	$d_{\mathcal{U}} = 1.3$		$d_{\mathcal{U}} = 1.5$		$d_{\mathcal{U}} = 1.95$		$d_{\mathcal{U}} = 2.01$	
	$C_S = 1$	$C_S = 0$	$C_S = 1$	$C_S = 0$	$C_S = 1$	$C_S = 0$	$C_S = 1$	$C_S = 0$
	$C_P = 0$	$C_P = 1$	$C_P = 0$	$C_P = 1$	$C_P = 0$	$C_P = 1$	$C_P = 0$	$C_P = 1$
(0,0;0,0)	0.5	1.8	0.04	0.2	-0.05	0.04	0.3	0.4
(0.85,0.85;-1,-1)	0.8	0.05	0.05	-0.7	-0.07	-0.01	0.4	0.5
(0.85,0.85;+1,+1)	0.4	0.3	0.03	-0.4	-0.04	-0.006	0.2	0.4
(0.85,-0.85;-1,+1)	0.2	0.7	0.01	0.08	-0.01	0.01	0.08	0.1

Table 2: Results for $R_{\mathcal{U}}^S$ ($C_K = 1$) with different values of C_S (C_P) at $\sqrt{S} = 500GeV$.

is found that the unparticle effects on $t\bar{t}$ production depend on its spin and scale dimension. The $M_{t\bar{t}}$ (P_t) distributions $R^{S(T)}$ ($r^{S(T)}$) for unpolarized and polarized beams are respectively shown in fig.3(4), where $U_{S(T)}(1.5)$ denotes the scalar (tensor) unparticle contributions with $d_{\mathcal{U}} = 1.5$, etc. Our results show that the effects of scalar unparticle are significant at unpolarized (polarized) photon collider for $M_{t\bar{t}} \geq 370GeV$ ($M_{t\bar{t}} \leq 362GeV$) and $P_t \geq 30GeV$ ($P_t \leq 25GeV$). One interesting phenomena is that for the scalar unparticle, a valley appears for R^S - (r^S -) distribution at $M_{t\bar{t}} \approx 368GeV$ ($P_t \approx 23GeV$). This effect is due to the interference between unparticle and SM contributions. We find when $0.02 \leq \lambda_S \leq 1.46$, a valley appears at some values of $d_{\mathcal{U}}$ (fig.5). This character may be used to determine the properties of scalar unparticle if it exists. Finally, the dependence of $t\bar{t}$ production induced by unparticle effects on the couplings is investigated (Table 3). One can find that $R_{\mathcal{U}}^{S(T)}$ becomes larger as the value of the coupling increases.

When using the propagators in ref. [12], there is no singularity for integer scaling dimensions.

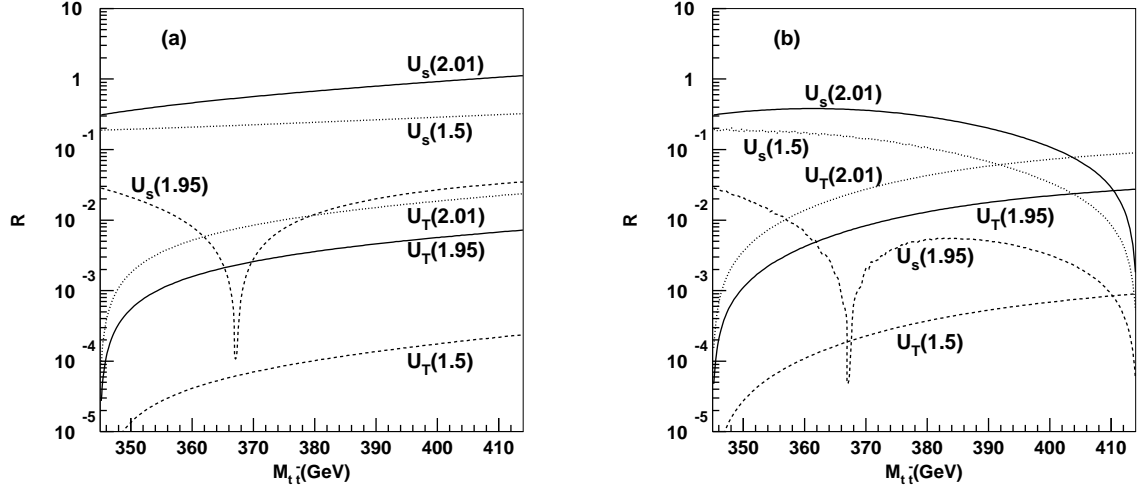


Figure 3: $R^{S(T)}$ -distribution for (a) unpolarized beams and (b) polarized beams with $(P_{e1}, P_{e2}; P_{L1}, P_{L2}) = (0.85, -0.85; -1, +1)$.

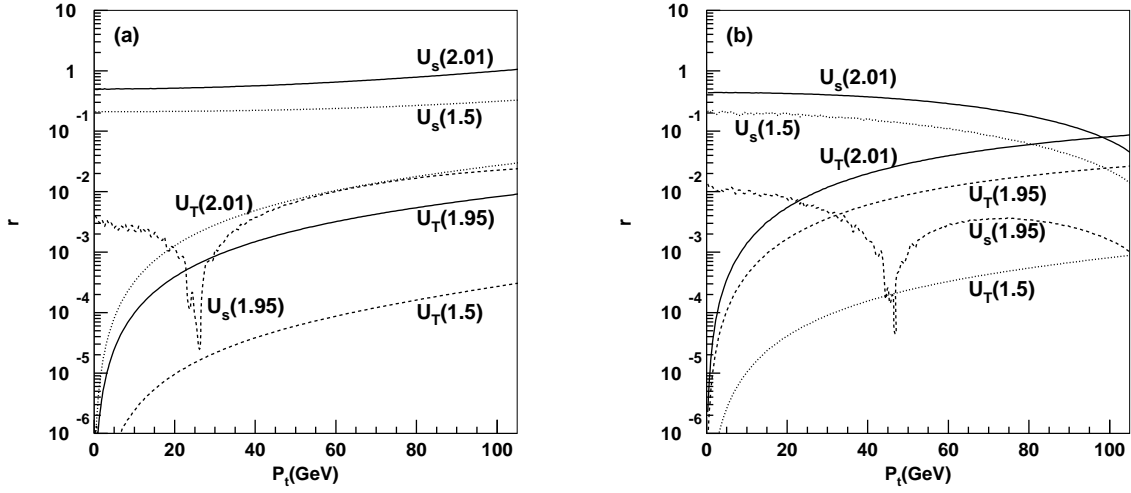


Figure 4: $r^{S(T)}$ -distribution for (a) unpolarized beams and (b) polarized beams with $(P_{e1}, P_{e2}; P_{L1}, P_{L2}) = (0.85, -0.85; -1, +1)$.

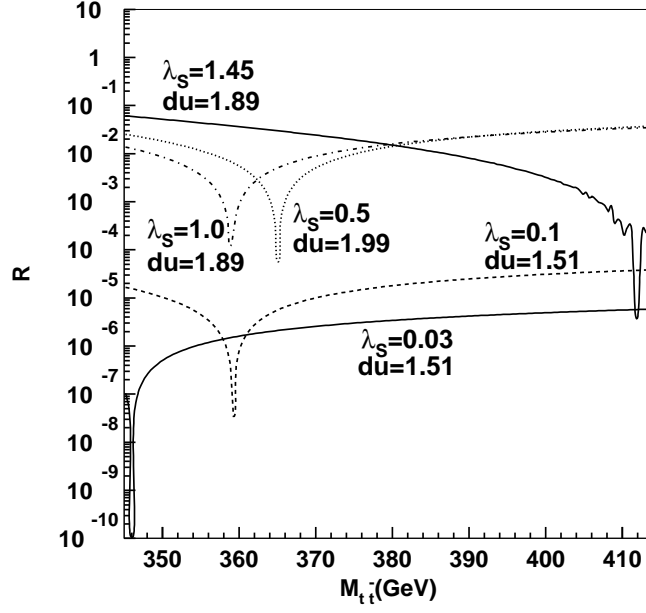


Figure 5: R^S -distribution for unpolarized beams which a valley appears.

	$R_{\bar{u}}^S$			$R_{\bar{u}}^T$		
	$\lambda_S = 0.1$	$\lambda_S = 0.3$	$\lambda_S = 1$	$\lambda_T = 0.5$	$\lambda_T = 1$	$\lambda_T = 3$
$d_{\bar{u}} = 1.1$	0.013	0.27	22.0	-0.017	-0.064	0.058
$d_{\bar{u}} = 1.5$	0.00002	0.002	0.247	0.000007	0.0001	0.0087
$d_{\bar{u}} = 1.9$	-0.0004	-0.0032	-0.015	0.0006	0.0006	0.023
$d_{\bar{u}} = 2.01$	0.0019	0.021	0.688	-0.003	-0.012	-0.091
$d_{\bar{u}} = 2.2$	0.00002	0.00019	0.002	-0.00003	-0.0001	-0.001
$d_{\bar{u}} = 2.8$	-0.0000002	-0.000002	-0.00002	0.0000004	0.000001	0.00001

Table 3: Results for $R_{\bar{u}}^{S(T)}$ with different coupling constants at $\sqrt{S} = 500\text{GeV}$.

4 Summary

Within SM, $t\bar{t}$ can be produced via u- or t-channel at photon collider. While unparticle can induce top quark pair production via s-channel. In this paper, we investigate $t\bar{t}$ production including unparticle effects at photon collider. We find that the unparticle effects depend on the unparticle spin and its scale dimension d_u . We investigate the dependence of the total cross section on Λ_u . If we assume that the predictions including unparticle effects are not far away from those obtained within SM, we can get some constraints on Λ_u . Our results show that scalar unparticle may play a significant role in $t\bar{t}$ production at photon collider. The $M_{t\bar{t}}(P_T)$ distributions related to scalar unparticle show that a valley exists when $0.02 \leq \lambda_S \leq 1.46$ for some values of d_u , which may be used to investigate the properties of scalar unparticle. Once the photon collider is available, it will become possible to investigate the unparticle physics or other unexpected new physics beyond SM.

Acknowledgments

This work is supported in part by NSFC, NCET and Huo YingDong Foundation. The authors thank all of the members in Theoretical Particle Physics Group of Shandong University for their helpful discussions.

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